Table of Contents

Refrigerant

Subject | Page

Introduction 3
What is ozone and why is it a cause for concern? 3
How Ozone is Formed and Destroyed 4
CFC's and Our Environment 6
CFC's and the Ozone Layer 8
Reaction Between CFC's and Ozone in the Atmosphere 9

Refrigerant - General Information 10
Chlorofluorocarbons (CFC's) 10
Stipulations for CFC R12 (as also for other CFC's) 10
Refrigerant and Global Warming 10
Refrigerant Chemical Properties 11
Physical Data of the Refrigerant 12
Methane is the Basis for R12 14
Ethane is Basis for R134a 14

Refrigerant Oil 15
PAG Oil 15

Initial Print Date: 10/07 Revision Date:

Refrigerant

Model: All

Production: All

OBJECTIVES

After completion of this module you will be able to:

- Describe how Ozone is formed.
- Describe the problems that affect our planet with the current usage of CFC’s.
- Identify the chemical composition of the refrigerant currently used in AC systems.

Introduction

What is ozone and why is it a cause for concern?

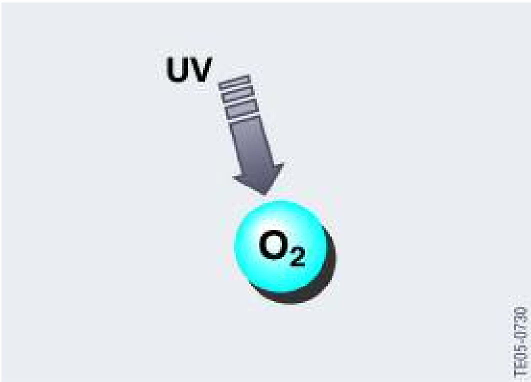
Ozone is an energy-rich modification of oxygen with three oxygen atoms in the molecule. It has the chemical symbol O_3. Ozone plays a decisive part in the chemical and biological processes on earth as it absorbs shortwave, solar UV radiation. With low ozone values in the stratosphere, larger quantities of UV-B-radiation could reach the earth's surface and cause serious problems for humans, animals and plants. On the one hand, ozone is an essential substance for life on earth, on the other hand, it can be harmful to humans, plants and animals when located near the earth's surface (troposphere). It is a proven fact that high ozone values near the ground can cause respiratory problems and can destroy the harvest of certain grain crops.

In 1985, a team of British scientists reported extremely low ozone values over Halley Bay in the Antarctic. This ozone hole was caused by the chemical reactions of chlorine and nitrogen.

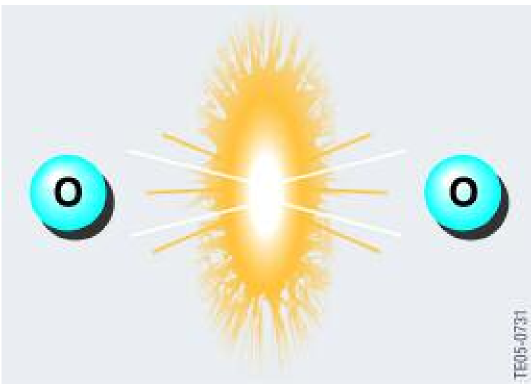
- Stratosphere: The atmospheric layer between an altitude of approximately 15 and 50 km
- UV-B: Wave length 280-320 nm; where 1 nm = 10-9 m
- Troposphere: The atmospheric layer between the earth's surface and an altitude of approx. 15 km.

Index	Explanation
1	Ozone in the stratosphere protects life on earth from harmful UV-B radiation
2	Ozone in the troposphere can impair the respiratory and lung function of humans and animals, damage plants and destroy the harvest of certain grain crops

How Ozone is Formed and Destroyed



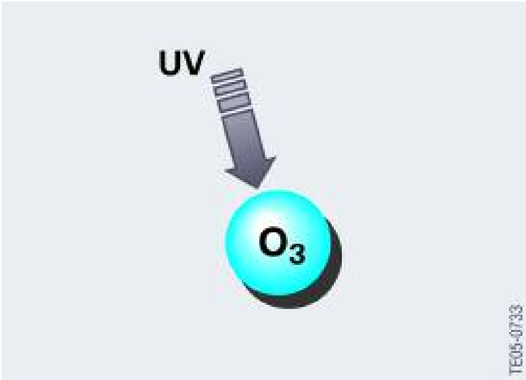
The air in the stratosphere is constantly influenced by the sun's UV radiation.



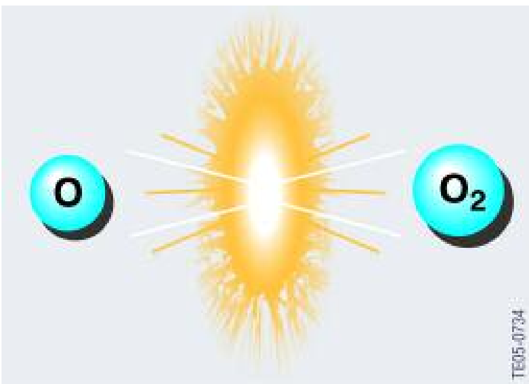
When these intensive UV rays hit an oxygen molecule (O_2), the molecule splits into two free oxygen atoms (O) (mono-atomic oxygen).

The free oxygen atom can now combine with an oxygen molecule.

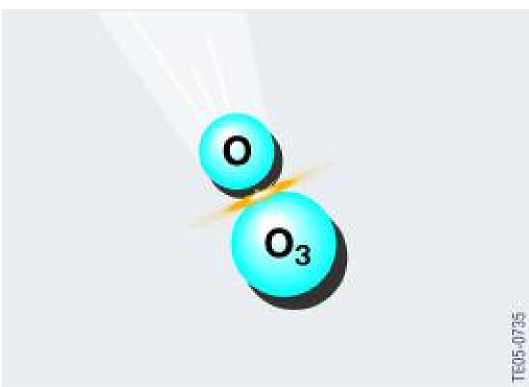
Together they form an ozone molecule (O_3).



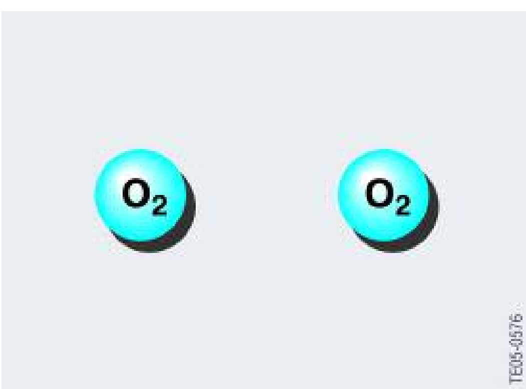
On the one hand, the ability of ozone to absorb large quantities of UV radiation makes it essential for life on earth while, on the other hand, it can lead to its own destruction.



When ozone absorbs UV rays.the ozone molecule splits into a free oxygen atom and a normal oxygen molecule.



The free oxygen atom can now collide with an ozone molecule and combine with it.



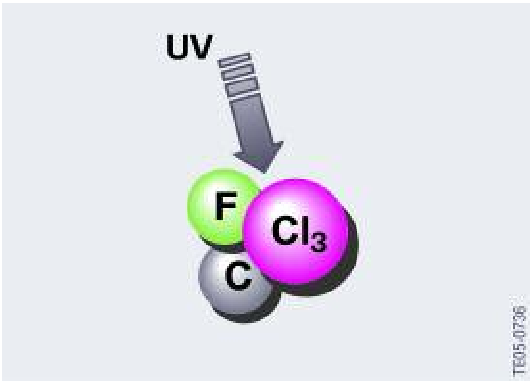
Two normal oxygen molecules then result from this combination.

CFC's and Our Environment

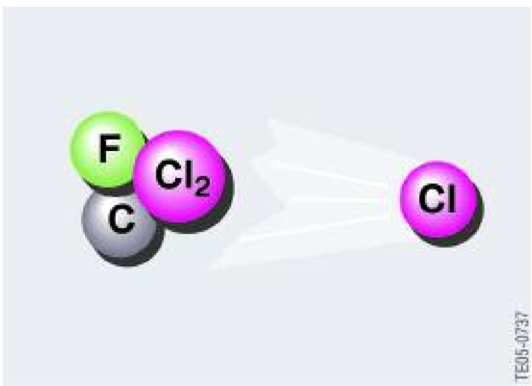
During the life of our earth, nature has controlled and balanced out the creation and depletion of ozone. This balance is easier to understand when compared to a bucket of water with a leak; the water level remains the same as long as the same amount of water is replenished. The earth's ozone layer behaves in the same way. As long as the same amount of ozone is created and depleted, the ozone layer will remain constant; however, if more ozone is depleted than is created, an ozone deficiency will occur that in the long term will lead to the so-called ozone hole.

In the last 20 years, scientists have established that man himself is largely responsible for the depletion of the ozone layer. One of the most significant causes for the destruction of the ozone layer is the manufacture and use of CFC products. The ever-growing mobility of humans, not only in individual passenger vehicle traffic but also in the area of public transport, e.g. ships and airplanes also contributes to the destruction of ozone. It takes a considerable amount of time for the exhaust gasses from motor vehicles and industrial plant to reach the stratosphere. The situation is somewhat different in the case of aircraft. They fly almost exclusively in the stratosphere with their CO emissions directly in this atmospheric layer.

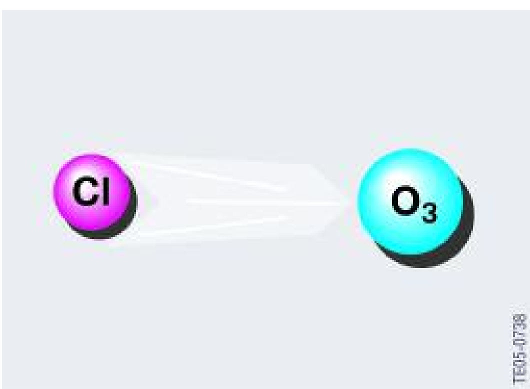
CFC5 vapors (CFC molecules) are relatively harmless near the earth's surface (troposphere) as here they are protected from the sun's UV rays. Unfortunately, these CFC molecules do not stay in the troposphere where they cause no or very little harm but rather they are conveyed upwards into the stratosphere as the result of a complicated mixing process. There the CFC molecules are constantly bombarded by UV rays from the sun. This results in a chemical reaction that destroys natural ozone.



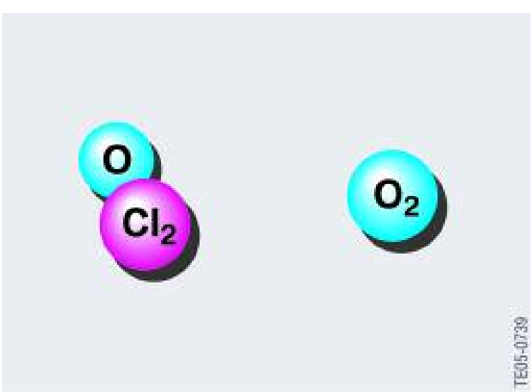
UV ray hits a CFC molecule.



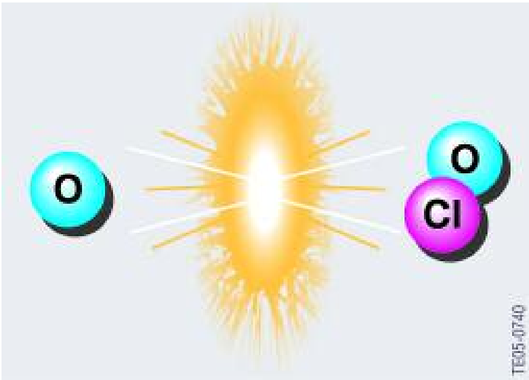
This causes a chlorine molecule (Cl) to split off.



The chlorine molecule collides with an ozone molecule.



It "steals" an oxygen atom and forms chlorine monoxide (Cl_2O). A normal oxygen molecule remains.



When a free oxygen atom collides with the chlorine monoxide molecule.

The 2 oxygen atoms form one oxygen molecule. The chlorine atom is released and goes on to destroy even more ozone molecules.

Scientific research has shown that CFC's are extremely harmful to our environment with particular emphasis on the free chlorine atoms. CFC's destroy the ozone layer which surrounds our earth as a protective envelope against radiation and is therefore a major contributing factor to the enlargement of the ozone hole. Added to this, it promotes the greenhouse effect which leads to progressive global warming with all its negative consequences such as worldwide increase in the sea level and climatic changes.

CFC's and the Ozone Layer

Chemically, CFC is very stable and can remain for 60 to 120 years in the atmosphere. The earth's atmosphere is made up of various layers. Our weather is generated in the layer closest to the earth's surface,(troposphere). Here, CFC's resist the natural depletion processes, (it does not break down into individual molecules).

After ascending for a period of 5 to 10 years, the CFC reach the next higher layer, the stratosphere containing ozone (as from an altitude of approx. 15 km). Here, the prevailing radiation conditions are considerably more intensive.

Above all, it is the powerful ultraviolet (UV) radiation that breaks down the CFC molecules thus releasing the chlorine atoms which were previously bound in the molecule.

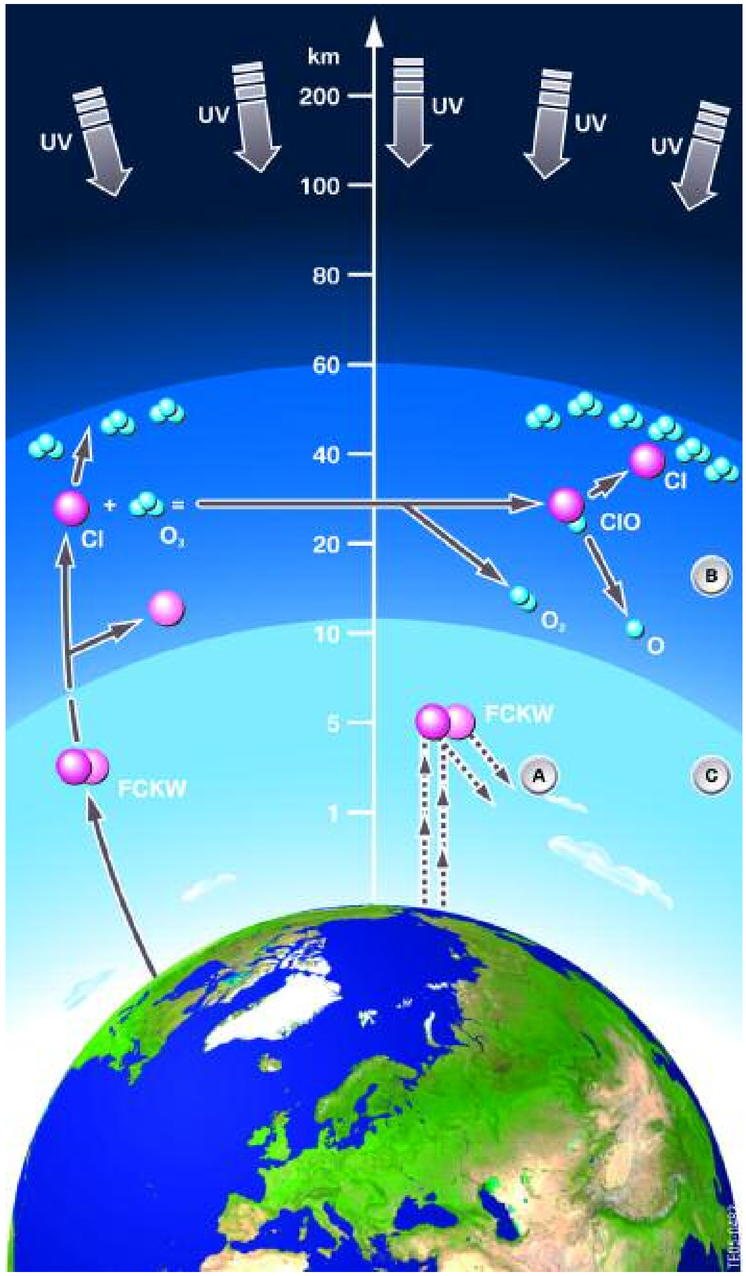
UV radiation splits ozone (O_3) into one oxygen molecule (O_2) and one oxygen atom (O). Oxygen atoms and molecules from other reactions recombine with ozone. This process takes place in the ozonosphere, a part of the stratosphere at an altitude of 20 to 50 km.

Reaction Between CFC's and Ozone in the Atmosphere

Chlorine (Cl) is a constituent of a CFC refrigerant such as R12. When not handled properly, the R12 molecule rises - (as it is lighter than air up to the ozone layer). Due to UV radiation, a chlorine atom in the CFC is released and reacts with the ozone. Consequently, the ozone breaks down and an oxygen molecule (O_2) and chlorine monoxide (ClO) remain, subsequently reacting again with oxygen to release chlorine (Cl). This cycle can be repeated up to 100,000 times.

Free oxygen molecules (O_2), however, cannot absorb UV radiation. The ozone layer is vital to us. The high ozone content of the stratosphere forms a natural protective shield - particularly against UV rays. Intense radiation causes an acceleration in the extinction of flora species, general growth is curbed.

Mammals and humans are more susceptible to disease, the cancer rate (particularly skin cancer) increases. Ozone depletion is ascertainable worldwide, the so-called ozone hole is growing, the trend for the future is already pre-programmed today. Each gram of CFC that escapes into the atmosphere is one gram too much.



Index	Explanation
A	Greenhouse effect
B	Stratosphere
C	Troposphere

Refrigerant - General Information

Chlorofluorocarbons (CFC's)

The need to develop chlorofluorocarbons (CFC's) stems from the demand for a coolant that was to have neither toxic nor combustible properties and was not to be volatile.

The CFC with the name dichlorodifluoromethane was developed by the chemists "Midgley" and "Henne" and was produced under the trade name Freon 12 as from1931. At that time, Freon 12 represented a significant new development. It could replace the high-risk substances such as ammonia and methyl chloride that required stringent safety measures. In the years that followed, CFC's were developed for the most diverse range of applications (low temperature applications in refrigeration technology, foaming agents for the aerosol industry, medical propellant in spray cans). Products containing CFC's came under pressure as the discussion concerning the ozone hole flared up in the 1970s. Alternatives to CFC's had to be found in order to stop the ozone depletion.

The 1987 Montreal Protocol which was signed by 46 states stipulated a gradual step by step reduction of halogenated CFC's by 50%. The signatory states make up 75% of the total CFC production capacity.

The United States Congress amended in 1990 the Clean Air Act. The far more stringent CFC-halon prohibition ordinance applies in Germany that was made law by the Federal government in 1991.

Stipulations for CFC R12 (as also for other CFC's)

- Stop production of R12 as of January 1, 1995.
- Import prohibition from third countries into EU countries.
- Filling ban in motor vehicle air conditioning systems as of July 1998

Note: Legislation is currently working on an ordinance that will further restrict trade in R12 already in the market as technically perfected alternatives are available.

Refrigerant and Global Warming

Solar radiation or insolation on the earth's surface is reflected as infrared radiation. However, trace gasses - the most important being CO_2 - also reflect these waves in the troposphere. This results in a climatic heating effect known as the greenhouse effect or global warming. CFC's have a high share of the growing trace gas concentration. By preventing the reflection or retaining the heat radiation, the greenhouse effect results in global warming with incalculable climatic changes with the following affects:

- Melting of the polar caps; worldwide increase in sea level (flooding)
- Serious climatic changes; Expansion of the deserts, increased evaporation = higher precipitation, displacement of sea currents, increased occurrence of tornados, etc.

Refrigerant Chemical Properties

- R134a (tetrafluoroethane) has a different chemical composition than R12 (dichlorodifluoromethane) and has no chlorine atoms.
- R12 is colorless and odorless, R134a has a slight ether-like odor.
- R134a more readily absorbs moisture than R12 (strongly hygroscopic due to asymmetric hydrogen atom distribution).
- R134a corrodes copper and various seal and component materials in R12 systems. R134a must therefore never be used in an R12 system as this would result in its rapid destruction.

Note: Escaping or leaking R134a vapors form decomposition products with high irritation and warning effects on contact with fire and glowing objects.

The name of the refrigerant is derived from the composition of their molecules.

R134a	Explanation
R	Refrigerant
1 and 3	Chemical designation of Carbon and Hydrogen atom composition
4	Number of Fluorine atoms
a	Asymmetric Hydrogen distribution in the molecule

Only the refrigerant R134a is used in today's motor vehicle air conditioning systems. R134a is a fluorohydrocarbon and has no chlorine atoms as in the refrigerant R12 that has a harmful effect on the ozone layer in the earth's atmosphere. It is invisible as a gas and colorless in a vapor and liquid state.

Although the substitute refrigerant R134a has no ozone depletion potential (ODP = 0), it does have a global warming potential of approx. 30% (GWP = 0.3) of R12 used as a comparison standard (ODP = 1.0 and GWP = 3.0).

Note: 1 kg of R12 has the same greenhouse effect as 4000 t of CO_2. R134a contributes to a very small extent to global warming. The ozone depletion potential equals zero.

The vapor-pressure curve of R134a is very similar to that of R12. The refrigerating capacity approximately corresponds to that of R12.

It is possible to convert air conditioning systems designed for R12 to R134a with a special conversion kit (retrofit)

The refrigerant must not be mixed, i.e. only the specific refrigerant intended for the respective air conditioning system must be used.

The types of refrigerant used are dichlorodifluoromethane (R12) that boils at -29.8°C and tetrafluoroethane (R134a) that boils at -26.5°C. .

Note: The specified boiling points correspond to the boiling temperature at standard atmospheric pressure (760 torr = 1013.25 mbar).

Physical Data of the Refrigerant

The critical pressure means that there is no longer a separating surface between liquid and vapor above this pressure and vapor above this pressure. A substance above its critical point is always in a vapor state. Condensation is no longer possible when a gas is heated beyond the critical point.

Physical data of the Refrigerant	R12	R134a
Chemical formula	CCl2F2	CH2F-CF3
Chemical designation	Dichlorofluoromethane	Tetrafluoroethane
Boiling point at 760 torr	-29.8°C	-26.5°C
Solidification point	-158°C	-101.6°C
Critical temperature	112°C	100.6°C
Critical pressure	41.58 bar	40.56 bar

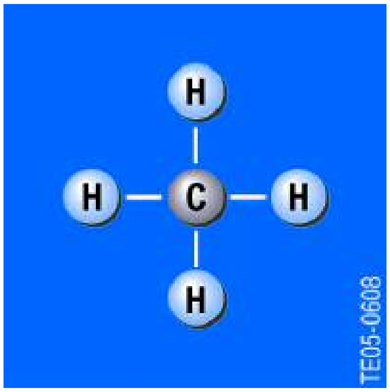
At temperatures below the critical point, all types of refrigerant in pressure vessels exhibit a liquid and vapor phase, i.e. there is a vapor cushion above the liquid. The pressure in the container depends on the ambient pressure for as long as, in addition to liquid, there is still vapor in the container (see vapor-pressure table).

The boiling point of a liquid specified in tables always refers to the atmospheric pressure of 1 bar. The boiling point of a liquid changes if the pressure above it changes. All homogeneous liquids behave in this way.

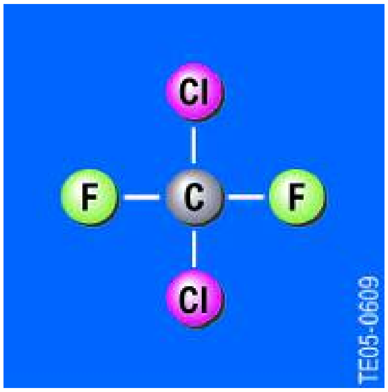
The R134a/R12 vapor-pressure curves show that, for example at constant pressure, the vapor becomes liquid due to a drop in pressure (in the condenser) or that the refrigerant changes from the liquid to the vapor state due to a drop in pressure (evaporator) Corresponding to the vapor-pressure curve, the table of vapor pressures is derived as a function of temperature for R12 and R134a.This table can be used to determine the evaporation temperature and pressure.

Temperature in °C	Pressure in bar R12	Pressure in bar R134a
-50	0.39	
-45	0.50	0.39
-40	0.64	0.51
-35	0.81	0.66
-30	1.00	0.84
-25	1.24	1.06
-20	1.51	1.32
-15	1.82	1.63
-10	2.19	2.00
-5	2.61	2.43
0	3.08	2.92
5	3.63	3.49
10	4.24	4.13
15	4.92	4.87
20	5.68	5.70
25	6.53	6.63
30	7.47	7.67
35	8.50	8.83
40	9.63	10.12
45	10.88	11.54
50	12.24	13.11
55	13.72	14.83
60	15.33	16.72
65	17.07	18.79
70	18.96	21.05
75	21.00	23.52
80	23.19	26.21
85	25.55	29.14
90	28.00	32.34
95	30.81	
100	33.73	
105	36.85	
110	40.18	
112	41.58	

Methane



Freon R12

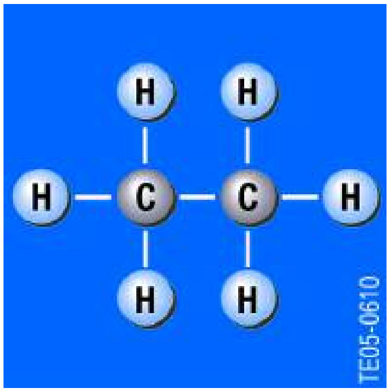


Methane is the Basis for R12

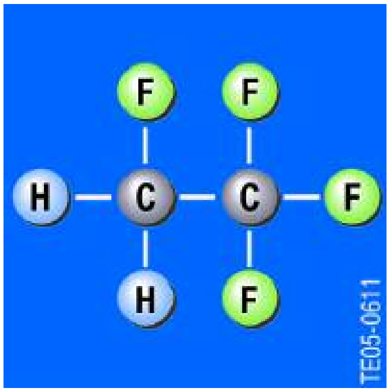
To obtain Freon R12, 2 hydrogen atoms are replaced by 2 chlorine or 2 fluorine atoms, resulting in the product dichlorofluoromethane (R12). Freon R12 is referred to as a fully halogenated hydrocarbon.

All hydrogen atoms have been replaced by halogens. Halogens include the substances fluorine (F), chlorine (Cl), bromine (Br) and iodine (I). Since chlorine destroys the ozone layer in the atmosphere, the fluorocarbon (FC) R134a was developed as a substitute for the refrigerant R12.

Ethane



R134a



Ethane is Basis for R134a

R134a has no chlorine atom and therefore also no ozone depletion potential. The hydrocarbon ethane serves as the basis for the production of R134a.

In the case of ethane, four of six hydrogen atoms are replaced by fluorine atoms, producing a product with the chemical designation tetrafluoroethane (R134a)

The term hydrogen atom, as well a fluorine or chlorine atom, is not entirely correct in this case; as from a chemistry point of view, these substances exist in molecular form.

Refrigerant Oil

A special refrigerant oil is necessary to lubricate all moving parts in the air conditioning system. No oils other than refrigerant oil must be used as they may cause copper deposits, coke formation, varnishing or foaming.This would result in the premature wear and destruction of the moving parts.

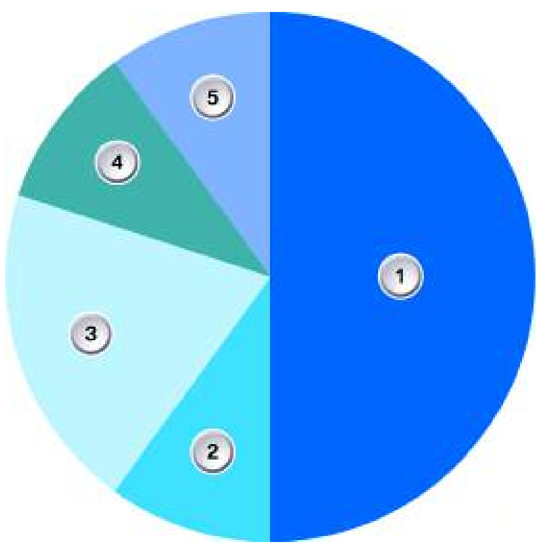
Polyalkylene glycol (PAG) oil is special synthetic oil that has been developed and is only to be used for refrigerant circuits with R134a. The refrigerant oil can also be used together with a certain type of compressor.

PAG Oil

- Mixable and compatible with the refrigerant itself
- Good lubricating properties
- Is Hygroscopic (absorbs humidity)
- Acid free
- Maintains the seals in the system

Note: R12 systems use mineral oil retrofitting and PAG oil can never be mixed with mineral oil. Ester oil is compatible with both mineral and PAG thus it is used when retrofitting a R12 system to R134a.

Oil Distribution in a Typical Refrigerant Circuit



Index	Explanation
1	Compressor 50%
2	Intake hose 10%
3	Evaporator 20%
4	Liquid reservoir 10%
5	Condenser 10%